TITLE

MODULAR PAINTING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. provisional patent application serial no. 60/420,612 filed October 23, 2002, the U.S. provisional patent application serial no. 60/ 420,971 filed October 24, 2002, and the U.S. provisional patent application serial no. 60/ 423,636 filed November 4, 2002.

BACKGROUND OF THE INVENTION

The present invention relates generally to robotic painting systems and, in particular, to an apparatus, method, and system for painting external surfaces of vehicle bodies.

Prior art paint booths are well known. A typical prior art paint booth, used to paint the exterior surfaces of vehicle bodies in both continuous conveyance and stop station systems, includes an enclosure housing a plurality of paint applicators. In one configuration, the applicators are mounted on an inverted U-shaped support structure that includes two vertical supports, one on either side of the path of travel of the bodies, connected at their tops by a horizontal support. This support structure is used to paint the top surfaces of the body and the horizontal beam can be fixed or can have an additional degree of freedom to move along the top of the vehicle body being painted. Another painting device is used in the same painting zone to paint the sides of the body and generally does not have the capability to move laterally along the length of the body. Disadvantages of this type of painting apparatus include lack of flexibility to provide optimized standoff distance between the body surface and the applicator along with inefficient use of the allotted painting cycle time. In the case of the top surface painting machine, the paint applicators are mounted on a common beam: therefore, the distance between each paint applicator and the surface to be painted varies with the contours of the vehicle body. In the case of the side painting machine, the paint applicators do not move transverse to the path of the vehicle body. They can only paint the portion of the body that is in front of the applicator leaving a good portion of the available cycle time unused.

An alternative to the support structure has been floor-mounted robots disposed along the sides of the painting booth. The robots mount either spray guns or rotary applicators (bell machines) for directing atomized paint toward the vehicle body.

While rotary applicators have advantages over spray guns, there are some associated disadvantages. The prior art floor mounted robots, especially bell machines, are inherently very costly and limit visual access to the booth. The bell machines require more bells for the same throughput due to limited orientation capability. The additional bells use more paint per vehicle due to per bell paint waste during color changing. Prior art floor mounted robots also require significant booth modification when installed in existing paint booths, increasing installation time and cost, and require more booth length and width. The rail axis of floor mounted robots requires doors at both ends of the booth. The waist axis of the floor mounted robot requires an additional safety zone at the ends of the spray booth and the rail cabinets of the floor mounted robots encroach into the aisle space. Floor mounted robots also require frequent cleaning due to the down draft of paint overspray causing paint accumulation on the robot arm and base, which results in higher maintenance and cleaning costs.

The prior art bell zone machines also lack flexibility. Additional and more flexible robot zones are required because the prior art machines unable to reach substantially all paintable surfaces on one side of the body and, therefore, have limited backup capability for an inoperative painting machine. Additional robot zones are also used to provide backup capability for the less flexible prior art painting machine.

It is desirable, therefore, to provide a painting apparatus and a painting system that utilizes robots in an efficient and cost-effective manner that minimizes paint waste, occupies little space (length and width) in the paint booth and can be installed in existing paint booths without requiring significant booth modification. It is also desirable to provide a painting apparatus wherein one painting robot is able to reach substantially all paintable surfaces on one side of the article to provide backup capability in the case of an inoperative robot.

SUMMARY OF THE INVENTION

The present invention concerns an apparatus, method, and system for painting objects in a paint booth or similar enclosure.

The present invention concerns a modular elevated rail adapted to be mounted in a paint booth for automated painting of conveyed articles such as automotive vehicle bodies. The modular elevated rail includes a frame enclosure having overhead-mounted rails straddling the line of conveyance of the articles. The conveyed articles may be moving or stationary during the painting process. The frame enclosure allows for higher rigidity and lower weight than is attained by conventional free standing, cantilevered rail mounts and occupies less space and realizes lower cost and less floor loading. At least one painting robot is mounted on a mounting location on the rail frame to move alongside, and at a higher elevation than, the articles such as to protect the rails from paint overspray and reduce the cost of covers for, maintenance of, and cleaning of the rails. The elevated rail frame in accordance with the present invention may be advantageously incorporated as part of a new paint booth assembly or installed as a retrofit device without requiring significant modification to the existing paint booth. The tubular arrangement of the modular elevated rail allows pre-wiring to be done at the production facility as opposed to an on-site wiring installation, providing numerous cost and quality-control benefits.

Preferably, a robot that provides four degrees of freedom is mounted on the frame rail, which provides another axis of freedom. The robot mounting location allows one painting robot to reach substantially all paintable surfaces on one side of the article in a degraded mode of operation. Preferably, opposed robots are provided for symmetric painting of the article. The robot primary axes (robot arms) advantageously operate in a vertically extending planar space. When an axi-symmetric paint applicator, such as a rotary bell, is mounted on the robot for painting, a sixth degree of freedom (orientation about the robot wrist faceplate) is not required as in the prior art. The sixth degree of freedom may be added if the application requires an asymmetric applicator.

The combination of the arm geometry of the robot and the mounting location of the elevated rail provides higher bell on time with minimal impact on booth size, allowing fewer robots to be installed in a small booth, and permitting use for painting in the space provided by existing booths.

DESCRIPTION OF THE DRAWINGS

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

Fig. 1 is a perspective view of a modular elevated rail apparatus in accordance with the present invention;

Fig. 2 is fragmentary perspective view of an alternate embodiment of the elevated rail apparatus according to the present invention shown installed in a painting booth;

Fig. 3 is a fragmentary cross sectional view of a portion of the elevated rail apparatus of Fig. 1 installed in a painting booth in a first configuration;

Fig. 4 is a fragmentary cross sectional view similar to Fig. 3 showing the elevated rail apparatus installed in a painting booth in a second configuration;

Fig. 5 is a perspective view of one of the painting robots shown in Fig. 1; and

Fig. 6 is a front elevation view of the elevated rail apparatus of Fig. 1 installed in a painting booth for painting a vehicle body.

DESCRIPTION OF THE PREFERRED EMBODIMENT

There is shown in Fig. 1 a modular elevated rail apparatus **10** for painting articles or objects in accordance with the present invention. The elevated rail apparatus **10** is adapted to be disposed in a paint booth as discussed below. The apparatus **10** includes a pair of frame rails **11** extending in a horizontal direction and spaced apart a predetermined distance on opposite sides of an axis **12** defining a path of travel for objects to be painted. Each end of each of the frame rails **11** is supported on an upper end of an associated one of a plurality of legs **13** adapted to engage a floor of the painting booth. Corresponding ends of the frame rails **11** can be connected by cross support members **14** that cooperate with the frame rails **11**, the legs **13** and the booth floor to form a modular, supporting rigid box frame structure of the apparatus **10**. If required for support, additional ones of the legs **13** and the members **14** can be attached intermediate the ends of the frame rails **11**. The cross supports **14** may be substituted by a booth structure specifically designed to couple the two frame rails **11** in a rigid box frame structure.

The frame rails **11** each have at least one mounting base **15** attached thereto. Three such bases **15** are shown on each of the rails **11**. Each of the mounting bases **15** is adapted to retain a painting device **16**. The preferred painting device **16** is a robotic four axis articulated arm terminated at a free end by a paint applicator **17**. The arm includes a shoulder axis, an elbow axis, a wrist rotating axis and a wrist tilting axis. Although a rotary bell atomizer is shown as the paint applicator **17**, any known device such as a spray gun could be used. The painting device **16** and the mounting base **15** move together parallel to the longitudinal axis **12** to provide a fifth axis of movement. The painting device **16** is provided with electrical power and fluids, such as paint, compressed air and solvent, through a flexible ribbon **18** connected between the painting device and the frame rail **11**. Preferably, the painting devices **16** are mounted in opposed pairs for simultaneously painting opposite surfaces of an object such an automobile body or the like (not shown) conveyed through the apparatus **10** along the axis **12**. If the shown location of the axis **12** represents the top surfaces of the objects being painted, the frame rails **11**, the support members **14** and the mounting bases **15** may be advantageously spaced a predetermined vertical distance **19** above the horizontal plane containing the axis **12**.

The elevated rail apparatus **10** can easily be installed as a new painting booth is constructed, or as a retrofit to an existing paint booth without requiring significant modification to the existing paint booth. The frame rails **11**, the legs **13** and the support members **14** can be brought into a painting booth and assembled into the rigid frame structure. Although the elevated rail apparatus **10** is described in terms of a painting process, the paint applicator **17** can be any tool suitable for performing a process on an object conveyed to the space between the two rails **11**.

An alternate embodiment of the elevated rail apparatus according to the present invention is shown in Fig. 2 as an apparatus **20** installed in a painting booth **21**. The painting booth **21** includes a rear or exit wall **22**, a lower wall or floor **23**, a front or entrance wall **24**, a pair of side walls **25** and a top wall or roof **26**. The right side wall **25**, the front wall **24** and the top wall **26** are cut away to permit the interior of the booth **21** to be seen. The walls **22** through **26** are connected together to define an enclosed space in which the elevated rail apparatus **10** of Fig. 1 may be advantageously disposed. However, the alternate embodiment elevated rail apparatus **20** is adapted to be disposed

in an upper portion of the paint booth **21** on the side walls **25**. The apparatus **20** includes the frame rail **11** extending along an interior surface of the left side wall **25**. The frame rail **11** can be attached to the side wall **25** by any suitable means. A second one of the frame rails **11** (not shown) is positioned on the opposite interior surface of the right side wall **25** such that the booth connects the frame rails **11** in a rigid frame structure. Movably attached to the frame rails **11** are the mounting bases **15** with the painting devices **16** and the painting applicators **17**.

There is shown in Fig. 3 a portion of the apparatus **10** at a side wall of the painting booth. The side wall is split with an upper portion **25a** above the frame rail **11** and a lower portion **25b** below. The upper portion **25a** abuts an upper surface **11a** of the frame rail **11** near an outer side surface **11b**. The lower portion **25b** abuts a lower surface **11c** of the frame rail **11** near an inner side surface **11b** to which the cross support member **14** is attached. Thus, the frame rail **11** forms a part of the side wall separating an interior space **27** of the painting booth from an aisle **28** outside the booth. The frame rails **11** are made of tubular stock and are preferably rectangular in cross section having a hollow interior **11e**. Alternatively, the frame rails **11** are formed from any shape of tubular stock including, but not limited to, circular stock. A coupling conduit **29** is attached to the surface **11b** for routing electrical and fluid lines from the aisle **28** into the interior **11e** of the frame rail **11**. The cross support members **14** also are tubular for routing electrical and fluid lines. The frame rails **11** and the cross supports **14** can be sealed, purged and pressurized to function in the painting booth environment.

There is shown in Fig. 4 a portion of the apparatus **10** at the side wall **25** of the painting booth wherein the entire apparatus **10** is located in the interior **27** of the booth. A coupling conduit **30** is attached to the surface **11b** for routing electrical and fluid lines into the interior **11e** of the frame rail **11**. The coupling conduit **30** extends through the side wall **25** into the aisle **28**.

Elevating the frame rails **11** above the path of the upper surfaces of the objects being painted allows a simple means for connecting the cross support members **14** between the opposing frame rails providing a path for any supply lines. Thus, the electrical power and fluid sources can be located in the aisle **28** adjacent the exterior of the left side wall **25**, for example, to supply the painting devices **16** on both sides of the

booth. Also, it is advantageously less costly than adding support steel to the paint booth to support the cantilever loads of traditional prior art floor mounted robot rails.

In addition, elevating the frame rails **11** places many of the typical maintenance components such as linear axis drive components and cable and hose carriers (not shown) out of the area where the paint overspray would typically accumulate on equipment in a prior art down draft spray booth. These components do not need to be protected against the overspray as diligently as a prior art floor mounted rail. This advantageously lowers the cost for protective covers and seals (not shown) while lowering the ongoing maintenance cost over the life of the robots **16**. Elevating the frame rails **11** also permits unobstructed viewing into the paint booth **21**, through windows **31** (see Fig. 2) provided in the side wall **25**, which is a benefit for system operators. The elevated rail apparatus **10** and **20** also allows access doors (not shown) to be placed in the side walls **25** when they would typically be located at the rear wall **22** and the front wall **24** of the booth **21**. This again reduces the overall length of the booth **21**.

Furthermore, elevating the frame rails **11** above the object, such as a vehicle body, to be painted allows the booth **21** to be made narrower than required for a traditional five to seven axis robot and does not require installation of components in the aisle **28** that are typically found in prior art floor-mounted installations. The elevated frame rail **11** and the robots **16** also advantageously allow the arm of each of the robots, discussed in more detail below, to reach under itself and paint the side of the vehicle because the robot base is not trapped between the side wall **25** and the vehicle.

As shown in Figs. 1 and 2, a plurality of the articulated arm robots **16** is attached to the elevated frame rails **11** at various mounting bases **15** that move along the rails and allow the applicators **17** to follow an object to be painted, such as a vehicle body (not shown), as it moves through the paint booth **21**. The applicators **17** are preferably a circular spray pattern bell applicator. By installing multiple articulated arm robots **16** on the common frame rails **11**, the vehicle can be processed with each applicator **17** spraying for a higher percentage of time, and requiring fewer of the robots **16** and corresponding applicators **17** as compared to floor mounted systems.

With a simplified robot **16**, the design of the structural elements of the elevated rail apparatus **10** and **20** (the frame rail **11**, the legs **13** and the cross supports members

14) are fit within the narrow width space limitations of a standard bell zone paint booth **21**. Furthermore, utilizing the elevated rail apparatus **10** in conjunction with the higher flexibility of a multi-axis manipulator, discussed in more detail below, yields higher application efficiencies, and thereby reduces the length overall length of a traditional bell zone paint booth **21**.

As shown in Fig. 5, the preferred painting device **16** is a four axis articulated arm robot terminated at a free end of the arm by the paint applicator **17** shown as a rotary bell applicator. The robot **16** includes a first or inner arm portion **32** mounted at a first end to a robot base **33** for rotation about a shoulder axis **34**. A second or outer arm portion **35** is mounted at a first end to a second end of the inner arm **32** for rotation about an elbow axis **36**. A wrist **37** attaches the paint applicator **17** to a second end of the outer arm **35** and has a rotating axis **38** and a tilting axis **39**. The wrist **37** rotates the applicator **17** about the axis **38** which is generally parallel to a longitudinal axis of the outer arm **35** and rotates the applicator **17** about the axis **39** to tilt the applicator relative to the axis **38**. Thus, the robot **16** provides four axes of motion relative to the base **33** for movement of the arm portions **32** and **35**, the wrist **37** and the applicator **17** in vertical planes. A fifth axis of motion is a rail axis **40** provided through the attachment of the robot base **33** to the mounting base **15** (Fig. 1) for reciprocating movement of the robot **16** along the horizontal longitudinal axis of the associated frame rail **11** (Fig. 1).

Preferably, the structural components of the outer arm portion **35** and the wrist **37** are formed from a non-conductive material having suitable structural strength and impervious to the corrosive properties of solvents used in the painting environments, such as Lauramid A material. "Lauramid" is a registered trademark of Albert Handtmann ELTEKA Verwaltungs-GmbH of Biberach, Germany. The Lauramid A material is a castable polyamide Nylon 12G material that also provides for electrostatic isolation, cleanliness, cleaning capability, and weight advantages. Grounding of internal gearing (not shown) in the wrist **37** and other conductive components is not necessary for use in the paint booth **21** because they are suitably insulated. Non-grounded components are advantageously less likely to attract paint overspray resulting in a cleaner robot **16** requiring less maintenance and having better transfer efficiency of the paint to the vehicle, all resulting in less operating cost. The conductive components could also be charged at a lower or the same potential as the spray applicator.

A plurality of paint lines **41** is routed along the side of the inner arm **32** and connect to a color changer **42** mounted in the outer arm **35**. The outer arm **35** houses a paint canister (not shown) for receiving a supply of paint through a selected one of the lines **41** and dispensing the paint to the applicator **17**. Also housed within the outer arm **35** is a high voltage cascade (not shown) for electrostatically charging the paint for application to the object being painted.

Fig. 6 shows the elevated rail apparatus **10** installed in the interior **27** of the painting booth **21** for painting a vehicle body **43**. The base **33** and the shoulder axis **34** of each of the robots **16** are located above the horizontal plane of the axis **12** of movement of an upper surface **44** of the vehicle body **43** which maximizes the capability of the robots. A one of the robots **16** dedicated to painting the top **44** of the vehicle body **43** can advantageously paint a side **45** of the vehicle body if necessary in a degrade mode, such as if a one of the robots **16** dedicated to painting the side fails, because of the extension capabilities that the translation axes **34** and **36** provide. In addition, the elevated frame rails **11** and cross support members **14** allow for the placement of an enclosed process controller **46** (Figs. 5 and 6), which includes pneumatic valves and bell control components (not shown), below the robot base **33** and in the paint booth **21**, in an easily accessible type X purge enclosure.

The robot **16** being attached to the movable mounting base **15** on the elevated frame rail **11** allows the applicator **17** to follow the vehicle body **43** as it moves through the booth **21**. By utilizing multiple opposed robots **16** on opposed frame rails **11**, and by using a line tracking motion capability, the vehicle body **43** can be painted with each applicator **17** spraying for a high percentage of the available cycle time. For example, the robots **16** adjacent to the exit wall **22** (Fig. 2) can be spraying a portion of one vehicle body while the robots **16** adjacent to the entrance wall **24** can be spraying a portion of another vehicle body. Alternatively, if the vehicle body is conveyed to a stop within the space between the two rails 11, the robots 16 may still move along the rails to reach and paint all body surfaces desired to be painted.

The robot primary axes **34** and **36** advantageously operate the robot arm portions **32** and **35** in a vertically extending planar space orthogonal to the axis **12**. Opposed robots **16** are provided for symmetric painting of objects such as the vehicle body **43**. Preferably control lines (not shown) are run through, or along, the cross support members

14 in order for a single controller (not shown) to control a pair of the opposed robots **16** for painting the opposite sides of the vehicle body **43**.

The geometry of the robot **16** and the mounting base **15** allows one painting robot to reach substantially all paintable surfaces on the top **44** and one side **45** of the vehicle body **43** in a degraded mode of operation. The elevated rail apparatus **10** or **20** advantageously provides for the use of multiple robots **16** on the same frame rail **11** having the capability to paint various size vehicle bodies **43** within the paint booth **21**. The geometry of the robot **16** and the elevated mounting location also eliminates human safety issues associated with placing traditional prior art robots in proximity of manual spray zones. Because the robot **16** is a planar device operating in a plane orthogonal to the longitudinal axis of the frame rail **11** and does not have a waist axis as in the prior art floor mounted painting robots and rail robot systems, the robot **16** does not extend the applicator **17** beyond the ends of the spray zone with an appreciable reduction in booth length. Furthermore, the geometry of the robot **16** and the elevated mounting location allows the robot to extend underneath the frame rail **11** into a protected enclosure (not shown) so that the robot can be serviced while the remaining robots **16** in the paint booth **21** continue painting. The protected enclosure has provisions for use of dynamic limiting devices to ensure operator safety.

In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiment. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.